CHAPTER 7

PLANNING PLUMBING PROJECTS

The *NCF/Seabee PO 1 & C*, NAVEDTRA 12543, the *Battalion Crew Leader Handbook*, and *Seabee Planner's and Estimator's Handbook*, NAVFAC P-405, discuss general considerations of planning, estimating, and scheduling of projects. This chapter contains information you may need when planning plumbing projects.

RESPONSIBILITIES

You are the technical advisor during both the planning and execution phases of plumbing projects. You will be supervising crews in the field and following an approved project schedule. **Planning is not worth the paper it is written on unless it is executed properly on the job.**

TECHNICAL ADVISOR

As technical advisor, the battalion Operations Officer (S-3), your company, and crew expect you to have answers to their questions about plumbing jobs. You must have access to plans, specifications, plumbing codes, technical references, and manufacturers' manuals. You are not expected to know every detail of your rating. **You can be an effective technical advisor by knowing and using the resources available to you.**

Many problems will require you to make decisions based on personal experiences. Do not rely on rate training manuals or formal schools to provide you with everything you need to know to be a Utilitiesman. The extra effort of self-study, combined with on-the job training and field experience, will enable you to make recommendations with confidence.

PLANNER

Now that you are advising people on the technical aspects of installing and maintaining plumbing systems, you may become involved in the planning of these tasks.

Planning takes on many applications and phases. Home-port project planning results in a schedule that you should use to decide how and when your work is going to be done. The resulting precedence diagram, along with other available information about a project, can help you in managing and supervising your project.

SUPERVISOR

Your company should follow the construction schedule that was prepared during the home-port period. After arriving at the deployment site, you may need to make changes to the schedule to show actual conditions on the job, such as changes in personnel, equipment availability, or material delays. The schedule is designed to be a management tool to assist the supevisor. Used properly, the schedule will alert you to problems and job requirements in enough time to avoid project delays.

Coordinate your requirements with other companies and departments. For example, decide on material, equipment, and personnel requirements about 30 days in advance at the company level, 2 weeks in advance at the job supervisor level, and no less than 1 week in advance at the crew leader level. This should provide the time necessary for supporting elements of the organization to break out, deliver, and provide support to your job. The project you are working on should decide the amount of lead time planning you should allow. During home-port planning, you may not know the conditions on a particular jobsite. After being on the site, you may have to reevaluate the original schedule. Generally, you can make changes to the schedule within 45 days of crew arrival on the job. Good supevisors ensure equipment, material, tools, and other facilities are on the job when needed. Missing items require an extra trip back to camp; this affects both production and crew morale.

PLANNING, ESTIMATING, AND SIZING PLUMBING SYSTEMS

You will provide input on the planning, estimating, and sizing of plumbing systems. This input may concern installation techniques, types of material required, quantity and size of piping or fittings, and so forth. This section provides information you must consider for planning and estimating a plumbing project. The National Standard Plumbing Code, military specifications, and job specifications provide more concise information.

SANITARY SYSTEMS

Various types of pipe and fittings are used for sanitary waste and drainage. However, the location of the installation determines the type of material you must use. Threaded pipe that is underground requires coal tar protection. Install underground sanitary waste and drainage lines in a separate trench from the water-service line. The underground water service and the building drain or sewer should not be less than 6 feet apart horizontally and placed on undisturbed or compacted earth. When separate systems of sanitary drainage and storm building drains are placed in one trench, they should be placed side-by-side. A building sewer or building drain installed in fill dirt or unstable ground should be made of cast-iron soil pipe, except that nonmetallic drains may be used when laid on an approved continuous supporting system. Table 7-1 depicts code requirements for pipe usage.

Table 7-1.—Sanitary Waste and Drain Piping

PIPING MATERIAL	SEWERS OUTSIDE OF BUILDINGS	UNDERGROUND WITHIN BUILDINGS	ABOVEGROUND WITHIN BUILDINGS
ABS Pipe and Fittings, schedule 40 DWV (ASTM D2661)	✓	✓	✓
ABS Pipe - cellular core (ASTM F628) and DWV Fittings	✓	✓	✓
ABS Sewer Pipe and Fittings (ASTM D2751)	✓		
ABS and PVC Composite Sewer Pipe (ASTM D2680)	✓		
Brass Pipe 9ASTM B43)			✓
Cast-Iron Soil Pipe and Fittings - Bell and Spigot (ASTM A74)	✓	✓	✓
Cast-Iron Soil Pipe and Fittings - Hubless (CISPI 301, ASTM A888)	✓	✓	✓
Concrete Drain Pipe, Nonreinforced (ASTM C14)	✓		
Concrete Drain Pipe, Reinforced (ASTM C76)	✓		
Copper Pipe (ASTM B42)			✓
Copper Tube - DWV (ASTM B306) and Copper Drainage Fittings (ANSI B16,23)	✓	✓	✓
Copper Water Tube - K,L,M (B88) and Copper Drainage Fittings (ANSI B16,23)	✓	✓	✓
Galvanized Steel Pipe (A53) and Cast-Iron Drainage Fittings (ASME B16,12)		✓	
PVC Pipe and Fittings, DWV (ASTM D2665)	✓	✓	✓
PVC Sewer Pipe - Cellular Core (ASTM F891)	✓	✓	✓
PVC Sewer Pipe (PS-46) and Fittings (ASTM F789)	✓		
PVC Sewer Pipe (PSM) and Fittings (ASTM D3034)	✓		
Vitrified Clay Pipe - Standard Strength (ASTM C700)	✓		
Vitrified Clay Pipe - Extra Strength (ASTM C700)	✓	✓	
Lead Pipe and Fittings (FS WW-P-325B)			✓

(1) Plastic drain, waste, and vent piping classified by standard dimension ratio shall be SDR 26 or heavier (lower SDR number).

(2) Plastic sewer pipe classified by pipe stiffness shall be PS-46 or stiffer (higher PS number).

(3) Piping shall be applied within the limits of its listed standard and the manufacturer's recommendations.

Pay special attention to the joints so roots do not grow into the piping. The depth of the piping should be below the frost line. Also, you should encase the piping with concrete or sleeve it with a metallic material when laying piping under roadways.

It may be necessary to install the building sewer and the water-service pipe in the same trench (fig. 7-1). If so, use the following precautions:

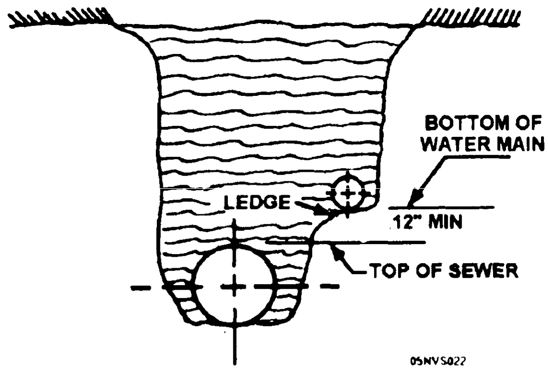

Figure 7-1.—Building sewer and the water-service pipe in the same trench.

- Ensure the bottom of the water pipe is at least 12 inches above the top of the building sewer.
- Place the water pipe on a solid shelf at the side of the trench.
- Use hot lead when joining cast-iron pipe for a building sewer; use a hot-poured compound in joining bell-and-spigot clay or concrete sewer pipe.
- After installation, test the building sewer with a 10-foot head of water, or equivalent test.

Grading

Install sanitary drainage piping on a uniform slope. This slope, pitch, grade, or drop per foot decides the flow velocity of liquid within the pipe. Piping with a diameter of 3 inches or less requires a slope of not less than 1/4 inch per foot. Pipe 4 inches or larger slopes no less than 1/8 inch per foot. This allows a velocity of not less than 2 feet per second, that provides the scouring action necessary to keep a pipe free from fouling. Sewer mains may have slopes of less than 1/8 inch per foot, as long as there is a cleaning velocity of 2 feet per second or greater. See table 7-1 (A) for code requirements.

Table 7-1 (A).—Discharge Rates and Velocities of Sloping Drains

Actual inside diameter of pipe in inches	1/16"/ft. slope Disch. gpm	vel fps	1/8"/ft. slope Disch. gpm	vel fps	1/4"/ft. slope Disch. gpm	vel fps	1/2"/ft. slope Disch. gpm	vel fps
1 1/4							3.40	1.78
1 3/8					3.13	1.34	4.44	1.90
1 1/2					3.91	1.42	5.53	2.01
1 5/8					4.81	1.50	6.80	2.12
2					8.42	1.72	11.9	2.43
2 1/2			10.8	1.141	15.3	1.99	21.6	2.82
3			17.6	1.59	24.8	2.25	35.1	3.19
4	26.70	1.36	37.8	1.93	53.4	2.73	75.5	3.86
5	48.3	1.58	68.3	2.23	96.6	3.16	137.	4.47
6	78.5	1.78	111.	2.52	157.	3.57	222.	5.04
8	170.	2.17	240.	3.07	340.	4.34	480.	6.13
10	308.	2.52	436.	3.56	616.	5.04	872.	7.12
12	500.	2.83	707.	4.01	999.	5.67	1413.	8.02

Chart shows gpm that will flow when pipe is half full. Half full means filled to half of the diameter of the pipe.
Computed from the manning formula for 1/2 full pipe, n = 0.015
For 1/4 full: multiply discharge by .274 and velocity .701
For 3/4 full: multiply discharge by 1.82 and velocity 1.13
For full: multiply discharge by 2.00 and velocity 1.00
For smoother pipe: multiply discharge and velocity by 0.015 and devide by "n" value of smoother pipe

Higher velocities, or greater drop per foot, will increase the carrying capacity of a drain. When designing fixture branches, keep in mind that a slope/drop of more than 1/4 inch per foot may cause siphonage of the trap seal.

Sizing Building Drains

The building drain in a sanitary system must be of sufficient size to carry off all the water and waste materials that may be discharged into it at any one time. The minimum allowable size is 3 inches for cast-iron pipe, but sound practice prescribes a 4-inch pipe, and most plumbing codes or ordinances require 4-inch pipe as a minimum. Increasing the size beyond that computed as required (the minimum of 3 inches still applies) does not increase the efficiency of the drain. The passage of liquid and solid waste through a horizontal pipe creates a natural scouring action, which is partially lost when the size of the drain is increased above the necessary size. The flow in too large a pipe is shallow and slow, and solids tend to settle to the bottom. The solids may accumulate to such an extent that they cause stoppages in the line. The optimum size of pipe should flow half full under normal use. This will create an efficient natural scouring action and still allow capacity for peak loads.

The standard method used in determining the size of a building drain is the Unit System. Drainage fixture unit system values for standard plumbing fixtures have been established and some of the most common are shown in table 7-2. Use the trap size listing at the bottom of table 7-2 for estimating drainage fixture unit (d. f u.) values for fixtures that are not listed.

To select the correct size of pipe for a horizontal sanitary drainage system, you must first calculate the total volume of liquid waste, expressed in drainage fixture units, that the system will be subjected to. Assume, for example, that a plumbing installation is to consist of 20 water closets, valve-operated; 22 lavatories with 1 1/4-inch traps; 15 shower heads in group showers; 20 wall urinals; 2 service sinks with standard traps; and 4 floor drains (2-inch). The total discharge,

Table 7-2.—Drainage Fixture Unit Values for Various Plumbing Fixtures

Type of Fixture or Group of Fixtures	Drainage Fixture Unit Values
Automatic clothes washer (2" standpipe)	3
Bathroom group consisting of a water closet, lavatory and bathtub or shower stall:	
Flushometer valve closet	8
Tank-type closet	6
Bathtub (with or without overhead shower) 1 1/2" trap	2
Bidet 1 1/2" trap	3
Clinic sink	6
Combination sink-and-tray with food waste grinder 1 1/2" trap	4
Combination sink-and-tray with one 1 1/2" trap	2
Combination sink-and-tray with separate 1 1/2" traps	3
Dental unit or cuspidor	1
Dental lavatory	1
Drinking fountain	1/2
Dishwasher, domestic	2
Floor drains with 2" waste	3
Kitchen sink, domestic, with one 1 1/2" trap	2
Kitchen sink, domestic, with food waste grinder	2
Lavatory with 1 1/4" waste	1
Laundry tray (1 or 2 compartments)	2
Shower stall, domestic 2" trap	2
Showers (group) per head	2
Sinks:	
Surgeon's	3
Flushing rim (with valve)	6
Service (trap standard)	3
Service (P trap)	2
Pot, scullery, etc.	4
Urinal, pedestal, siphon jet blowout	6
Urinal, stall lip	4
Urinal stall, washout	4
Urinal trough (each 6-foot section)	2
Wash sink (circular or multiple) each set of faucets	2
Water closet, tank-operated	4
Water closet, valve-operated	6
Fixtures not listed above:	
Trap Size 1 1/4" or less	1
Trap Size 1 1/2"	2
Trap Size 2"	3
Trap Size 2 1/2"	4
Trap Size 3"	5
Trap Size 4"	6

expressed in drainage fixture units, would be calculated as follows from table 7-2.

Number and Type of Fixtures	Unit Values	Total Discharge
20 water closets (flush valve)	6	120
22 lavatories (1 1/4-inch traps)	1	22
15 shower heads	2	30
20 urinals (wall)	4	80
2 sinks (service)	3	6
4 floor drains (2-inch)	3	12
		270 d.f.u.

After calculating the total discharge and determining the slope of the piping and the velocity of flow, select the correct size of pipe by using table 7-3. Assume that the cast-iron house drain to be installed will have a slope of 1/4 inch per foot. From table 7-3, the minimum size pipe for the horizontal sanitary drainage system under discussion is 5 inches.

Table 7-3 is for cast-iron soil pipe or galvanized steel pipe house drains, house sewers, and waste and soil branches. When copper tubing is used, it may be one size smaller than shown in the table. Note that the size of building drainage lines must never decrease in the direction of flow.

When provision is made for the future installation of fixtures, those provided for must be considered in determining the required sizes of drainpipes. Construction to provide for such future installation should have a plugged fitting or fittings at the stack to eliminate any dead ends.

Sizing Stacks and Branches

The term *stack* is used for the vertical line of soil or waste piping into which the soil or waste branches carry the discharge from fixtures to the house drain. A *waste stack* carries liquid wastes that do not contain human excrement; a *soil stack* carries liquid wastes that do.

Most buildings do not have separate soil and waste stacks. A single stack known as the soil and waste stack, or simply the soil stack, serves to carry both soil and waste material. Soil stacks are usually made of cast-iron pipe with caulked joints. They may, however, be made of other materials

Table 7-3.—Maximum Loads for Horizontal Drains

Diameter of Drain	Horizontal Fixture Branch	Building Drain or Building Sewer — Slope			
		1/16-in/ft	1/8-in/ft	1/4-in/ft	1/2-in/ft
(inches)	(d.f.u)[1]	(d.f.u.)	(d.f.u.)	(d.f.u.)	(d.f.u.)
1 1/4	1				
1 1/2	3				
2	6				26
2 1/2	12			24	31
3	32[2]		36[3]	42[2]	50[2]
4	160		180	216	250
5	360		390	480	575
6	620		700	840	1000
8	1400	1400	1600	1920	2300
10	2500	2500	2900	3500	4200
12	3900	3900	4600	5600	6700
15	7000	7000	8300	10000	12000

[1]Drainage fixture unit.

[2]Not more than two water closets or two bathroom groups.

[3]Less than 2 feet per second.

such as galvanized steel or copper tubing. Branches are usually either threaded galvanized steel pipe with drainage (recessed) fittings or copper tubing.

Sizing the Stack

The stack is sized in the same way as the building sewer. The maximum discharge of the plumbing installation is calculated in drainage fixture units. This figure is applied to table 7-4 or table 7-5 to obtain the proper stack size.

Continuing our example, the 270 drainage fixture units would require a 5-inch stack, if the stack had less than three branch intervals. (No soil or waste stack should be smaller than the largest horizontal branch connected, except that a 4 x 3 water closet connection should not be considered as a reduction in pipe size.)

Offsets on Drainage Piping

An offset above the highest horizontal branch is an offset in the stack vent and should be considered only as it affects the developed length of the vent.

An offset in a vertical stack with a change in direction of 45 degrees or less from the vertical piping may be sized as a straight vertical stack. In piping where a horizontal branch connects to the stack within 2 feet above or below the offset, a relief vent should be installed.

A stack with an offset of more than 45 degrees from the vertical should be sized as follows:

1. The portion of the stack above the offset should be sized for a regular stack, based on the total number of drainage fixture units above the offset.
2. The offset should be sized as for the building drain. See table 7-3.
3. The portion of the stack below the offset should be sized as for the offset, or based on the total number of drainage fixture units of the entire stack, whichever is larger. A relief vent should be installed for the offset. Never connect a horizontal branch or fixture to the stack within 2 feet above or below the offset.

Table 7-4.—Maximum Loads for Soil and Waste Stacks Having Not More Than Three Branch Intervals

Diameter of Stack	Maximum Load: On Any One Branch Interval	Maximum Load: On Stack
(inches)	(d.f.u)[1]	(d.f.u.)
1 1/4	1	2
1 1/2	2	4
2	4	9
2 1/2	8	18
3	20[2]	48[2]
4	100	240
5	225	540
6	385	930
8	875	2100

[1]Drainage fixture unit.

[2]Not more than two water closets or bathroom groups within each branch interval nor more than six water closets or bathroom groups on the stack.

Sizing Individual Waste Lines

The water closet, strictly speaking, has no waste. It is usually connected directly into the stack on a short as possible separate branch of its own by the use of a closet bend. The closet bend is 3 or 4 inches in diameter if made of cast iron or steel and 3 inches if made of copper.

Because lavatories are used for washing hair, loose hair is often carried down into the waste pipe, causing a stoppage. Lavatory drainage is improved by using a minimum number of fittings and by eliminating long horizontal runs. The minimum pipe size for lavatory wastes is 1 1/4 inches, but 1 1/2 inches is more satisfactory.

Urinals present a particular problem because cigarette butts, cigar stubs, chewing gum, matches, and so on are often discarded in them. These materials can easily cause a stoppage. For this reason, urinals should be equipped with an effective strainer. Size of waste pipe should be at least 1 1/2 inches for wall-mounted urinals and 3 inches for the pedestal siphon jet urinal.

Shower wastes seldom cause trouble since they have a relatively clear water waste flowing through them. The usual diameter of the waste pipe for a single shower is 2 inches if made of cast iron or steel and 1 1/2 inches if made of copper.

A domestic kitchen sink requires a 1 1/2-inch cast-iron or steel waste pipe. When a sink is equipped with a garbage disposal unit, a minimum of 2 inches is required for the cast-iron or steel drainage piping.

Table 7-5.—Maximum Loads for Soil and Waste Stacks Having Four or More Branch Intervals

Diameter of stack (inches)	Number of Branch Intervals: 4, on any one interval	4, on stack	5, on any one interval	5, on stack	6, on any one interval	6, on stack	7, on any one interval	7, on stack	8, on any one interval	8, on stack	9, on any one interval	9, on stack	10, on any one interval	10, on stack
in.	d.f.u.[1]	d.f.u.	d.f.u.	d.f.u.	d.f.u.	d.f.u.	d.f.u.	d.f.u.	d.f.u.	d.f.u.	d.f.u.	d.f.u.	d.f.u.	d.f.u.
2	3	13	3	16	3b	18c								
3a	18a	72a	17a	85a	16a	96a	15ab	102ac						
4	90	360	84	420	80	480	76b	530c						
5	205	820	190	950	180	1,080	175	1,215	170	1,360	155b	1,400c		
6	350	1,400	325	1,625	310	1,860	299	2,090	290	2,320	285	2,560	280	2,800
8	785	3,140	735	3,675	700	4,200	675	4,725	655	5,240	640	5,780	630	3,300
10	1,405	5,620	1,310	6,550	1,200	7,500	1,205	8,435	1,170	9,360	1,145	10,310	1,125	11,250
12	2,195	8,780	2,045	10,225	1,950	11,700	1,880	13,160	1,825	14,600	1,790	16,090	1,755	17,550
15	3,935	15,740	3,675	18,375	3,500	21,000	3,375	23,620	3,280	26,240	3,210	28,880	3,150	31,500

Diameter of stack (inches)	Number of Branch Intervals: 11, on any one interval	11, on stack	12, on any one interval	12, on stack	13, on any one interval	13, on stack	14, on any one interval	14, on stack	15, on any one interval	15, on stack	16, on any one interval	16, on stack
in.	d.f.u.	d.f.u.	d.f.u.	d.f.u.	d.f.u.	d.f.u.	d.f.u.	d.f.u.	d.f.u.	d.f.u.	d.f.u.	d.f.u.
2												
3a												
4												
5												
6	265b	2,900c										
8	620	6,830	610	7,350	585b	7,600c						
10	1,110	12,200	1,095	13,100	1,080	14,070	1,070b	15,000c				
12	1,730	19,020	1,705	20,500	1,690	21,960	1,670	23,410	1,655	24,800	1,620b	26,000c
15	3,100	34,160	3,060	36,700	3,030	39,390	3,000	42,015	2,975	44,600	2,955	47,280

[1] Drainage fixture units.

a. Not more than two water closets or bathroom groups within any one branch interval and not more than six water closets or bathroom groups on the stack.

b. Loads on any one branch interval for higher stacks shall not exceed these values; however, this shall not prevent the installation of higher stacks.

c. Stack loads for higher stacks shall not exceed these values; however, this shall not prevent the installation of higher stacks.

There are two styles of service sinks (slop sinks): the trap-to-wall and the trap-to-floor. They are used for disposal of wash water, filling swab buckets, and washing out swabs. The trap-to-wall type requires a 2-inch or 3-inch waste pipe; the trap-to-floor, a 3-inch waste pipe. For both types, if copper tubing is used, a one size reduction is allowed.

Scullery sinks are large sheet metal sinks used for washing large pots and pans and for general scouring purposes. The large amount of grease that usually passes through a scullery sink makes a 2-inch waste pipe necessary.

Drinking fountains carry only clear water wastes and a 1 1/4-inch waste pipe is suitable. An indirect drain (covered later in this chapter) should be used.

Sizing Sanitary Collecting Sewers

The design and sizing of collecting sewers, the subtrunks, and the main trunk lines are provided by engineers. However, the UT should understand the factors that contribute to the design and the requirements that must be met.

While the unit system is used to size the building sanitary piping and the building drain, the sewage quantities used in sewer design normally are computed on a contributing population basis. The population to be used in design depends upon the type of area that the sewer is to serve. If the area is strictly residential, the design population is based on full occupancy of all quarters served. If the area is industrial, the design population is the greatest number employed in the area at any time. There are exceptions to the general rule that sewers must be designed on a population basis. Among these exceptions are laundry sewers and industrial-waste sewers. The per capita contribution for sewer design varies. Typical values are 100 gallons per person per day for permanent residents and 30 gallons per person in the industrial area per 8-hour period.

The sizing of the sewer includes the average rate and the extreme (peak) rate of flow (which occurs occasionally). The ratio of the peak rate of flow to the average rate of flow may vary with the area served, because the larger the area or the greater the number of persons served, the greater the tendency for flow to average out. Typical peak flows might range from 6 for small areas down to 1.5 for larger areas.

An allowance for infiltration of subsurface water is added to the peak flow to obtain the design flow. A typical infiltration allowance is 500 gallons per inch of pipe diameter, per mile of sewer per day.

Additional capacity to provide for population increase is usually included for areas that are likely to continue to develop. Provision of approximately 25 percent additional capacity over the initial requirements is advisable.

Each length of pipe from one manhole to the next is sized to carry the design flow. However, to help prevent clogging and to facilitate maintenance, a minimum size is usually specified which may be larger than is necessary to carry the design flow at the upper ends of the system. Typical minimum sizes are 6-inch pipe for house and industrial-waste sewers and 8-inch pipe for all other sewers.

It is sometimes the practice to select a pipe size that will carry the design flow when the pipe is half full, thus allowing for expansion. More often, however, sufficient safety factors in the future population estimate and the peak flow factor are included so the pipe may be designed to carry the design flow when flowing full.

The formulas or tables used in sizing the pipe are based on experiments and experience. One of the factors taken into account is the roughness of the pipe. Asbestos-cement pipe, for example, is smoother than concrete pipe. Because there is less friction on the inside of the asbestos-cement pipe, it will carry a greater flow than concrete pipe of the same size.

Another factor is the slope at which the pipe will be laid. The slope will generally be determined by the fall available on the natural ground area through which the sewer runs. The plans for collecting sewer systems generally show slope (or grade) in terms of fall per hundred feet. Slope is sometimes expressed as a percent rather than in inches per foot. A 1 percent slope means 1 foot of frill in a 100-foot length of pipe, or about 1/8 inch per foot. A 0.5 percent slope (6 inches in 100 feet is about 1/16 inch per foot.

Table 7-6 gives the minimum slope for some of the most commonly used pipe sizes. The slope should remain constant in the section between each manhole. Each section between successive manholes should be analyzed and the slope for that particular section determined. If the fall is relatively steep, the velocity of the flow is faster and a smaller pipe size may be used. If the slope is relatively flat, the velocity is slower and a larger pipe size may be used. In the larger pipe, the depth of flow may decrease to such extent that the velocity might be no greater than a smaller pipe

Table 7-6.—Minimum Slope for Sewer Pipe

Inside pipe diameter (inches)	Minimum fall (ft per 100 ft)
6	0.6
8	0.4
10	0.3
12	0.24
18	0.14

on the same grade. Therefore, an increase in pipe size to obtain the desired flow velocity is limited by the rate of flow. Typical minimum flow velocities are 2 feet per second when the design flow fills the pipe and 1.6 feet per second at the average rate of flow. Maximum velocities must also be considered; too high a velocity will erode the pipe. A typical maximum velocity is 15 feet per second for concrete pipe. Because of the differences in available slopes, smaller pipe may be used in some sections than is required in an upper section of the same sewer. The pipe size should be reduced whenever better flow conditions would result.

Manholes provide access to sewers for inspection and cleaning. They are placed where there is a change in grade, a change in pipe size, a junction of two or more sewerlines, or a change in direction. Otherwise, they are placed at intervals of 300 or 500 feet of sewerline. The manholes should be built so there is no decrease in velocity and a minimum of water disturbance. The channel should be deep enough to prevent sewage from spreading over the manhole bottom. The covers should be of a weight strong enough to support the expected traffic. Perforated covers should not be used for sanitary sewer manholes, because openings in the sewer manhole would permit the entrance of sand, grit, and surface water. The sewers are ventilated by the stacks of the building plumbing systems.

STORM DRAINAGE SYSTEMS

Storm drainage systems are designed to drain all surface and sometimes subsurface water that may cause damage to Navy facilities, property, or adjoining land. They consist of pipe, inlets, catch basins, and other drainage structures to carry the surface runoff and subsurface water to a point of disposal.

Storm drainage systems should be separate from sanitary sewage systems wherever possible. Some Navy bases may have combination systems still in use. However, storm water should never be drained into sewers intended for sanitary sewage only.

EOs and BUs generally are responsible for building ditches, culverts, and other structures that are a part of storm sewers. Therefore, construction of these facilities is not covered in this chapter.

The UT is generally concerned with only the pipework itself. This involves laying storm drain lines both inside and outside buildings and other structures. This pipe material may be the same as that used for the sanitary system. Storm sewer systems, however, may include pipe of much larger sizes than are needed for sanitary sewers. Plain or reinforced concrete pipe (rather than clay, cast iron, or asbestos cement) is generally used for the larger lines. Also, it is not so important that the joints be watertight in storm sewer systems. In fact, the mortar is sometimes omitted from a portion of the joint and washed gravel is placed next to the opening; the storm drain thus serves also as an underdrain to pick up subsurface water.

Installation Considerations

Storm and sanitary systems may differ in the installation of the piping. Building storm drains should generally be graded at least 1/4 inch per foot whenever feasible. This amount of drop per foot provides an unobstructed and self-scouring flow. However, a greater drop per foot may be given as no fixture traps which might lose their seals are associated with it.

When a change of direction is necessary, long radius fittings are used and a cleanout need not be installed. This is especially true in and under buildings. But a manhole is used outside of buildings when a change of direction is necessary, or when two or more lines are connected together.

Sizing Building Storm Drains

To determine the size of building storm drains, a number of factors must be considered, such as rainfall intensity, roof size, and pitch of roof. Tables have been made for use in estimating the size of pipe to select. One example is table 7-7; it shows storm drain sizes. Remember that this table is to be used only as a guide when estimating for storm drainage, as different areas have different intensities of rainstorms.

Another method for sizing building storm drains is to provide 1 square inch of pipe cross-sectional area for each 100 square feet of roof area. This method is easy to remember: 1 square inch for 100 square feet. (However, it is not as accurate as using table 7-7.) Using this method, you can prepare a table similar to table 7-8. Show the diameter in the first column; then the radius (which is one-half the diameter); then the square of the radius; then the cross-sectional area, which is *pi* (3.14) times the radius squared. Since each square inch may take 100 square feet of roof, move the decimal of the square inches over two places to the left (which is multiplying by 100) to get the area of the roof that may be drained to the pipe. As you can see by comparing table 7-7 with table 7-8, the second method is much more conservative.

Sizing Site Storm Sewers

While rules of thumb such as those just described are used to size building storm drains, different procedures are used to size the storm sewers that carry the runoff from the building site and surrounding land areas. The design and sizing of storm drains are provided by engineers. It is not necessary that the UT understand the factors that contribute to the design. Therefore, the information is not included here.

WATER SUPPLY SYSTEMS

After the pipe runs and fittings are located on a print or drawing, the size, quantity, and joining requirements of the pipe must be determined. When a plumbing print is available for the job, it will contain this information. If there is no blueprint, you must determine these requirements yourself. The quantity of pipe required and the number and types of fittings you intend to use

Table 7-8.—Fixture Demand

Fixture	Units[a]	Gallons per minute
Water closet	6	45
Urinal	5	39 1/2
Slop sink	3	22 1/2
Shower	2	15
Laundry tray	2	15
Bathtub	2	15
Kitchen sink	2	15
Lavatory	1	7 1/2

[a] 1 unit = 7 1/2 gallons per minute

Table 7-7.—Size of Horizontal Building Storm Drains and Building Storm Sewers

Diameter of Drain (inches)	Maximum Projected Area for Drains of Various Slopes					
	1/8-Inch Slope		1/4-Inch Slope		1/2-Inch Slope	
	Square Feet	gpm[2]	Square Feet	gpm	Square Feet	gpm
3	822	34	1,160	48	1,644	68
4	1,880	78	2,650	110	3,760	156
5	3,340	139	4,720	196	6,680	278
6	5,350	222	7,550	314	10,700	445
8	11,500	478	16,300	677	23,000	956
10	20,700	860	29,200	1,214	41,400	1,721
12	33,300	1,384	47,000	1,953	66,600	2,768
15	59,500	2,473	84,000	3,491	119,000	4,946

[1] Table 7-7 is based upon a maximum rate of rainfall of 4 inches per hour for a 5 minute duration and a 10 year return period. Where maximum rates are more or less than 4 inches per hour, the figures for drainage area shall be adjusted by multiplying by four and dividing by the local rate in inches per hour.

[2] Gallons per minute.

are easily determined by tracing the layout of the water supply system as drawn in a print or sketch. Determining the size pipe you will require to meet the fixture demand of a facility is more complicated and will be discussed in this section.

Sizing Cold-Water Supply Systems

Some factors that affect the size of the water service in a plumbing system are the types of flush device used on the fixtures, the pressure of the water supply in pounds per square inch (psi), the length of the pipe in the building, the number and kind of fixtures installed, and the number of fixtures used at any given time. The stream of water in a pipe is made up of a series of layers moving at different speeds with the center layer moving the fastest. The resistance to flow is called *pipe friction* and causes a drop in pressure of the water flowing through the pipe. Friction loss may be overcome by supplying water at greater pressure than would normally be required or by increasing the size of the pipe.

The two most important things to consider are the maximum fixture demand and the factor of simultaneous fixture use. The *maximum fixture demand* in gallons is the total amount of water that would be needed to supply all fixtures if they were being used at the same time for 1 minute. Since it is very unlikely that all fixtures would be turned on at the same time, a probable percentage of the fixtures in use at any given time must be found. This is the *factor of simultaneous use.* The more fixtures in a building, the smaller the possibility that all will be used at the same time. Therefore, simultaneous use factors decrease as the number of fixtures increase.

To estimate the maximum fixture demand in gallons, the number and type of all fixtures in the completed plumbing system must be known. Table 7-8 is used to obtain the maximum fixture demand. For example, assume a plumbing system consists of three urinals, two water closets, one slop sink, two shower stalls, one kitchen sink, one laundry tray, and four lavatories. From table 7-8 a maximum fixture demand of 321 gallons per minute (gpm) can be figured. Normally only a small percentage of fixtures would be used at the same time, so the maximum fixture demand is reduced by applying the factor of simultaneous use.

The factor of simultaneous use, also called the probable demand, is only an estimate. Table 7-9 gives data for making an estimate of probable demand. When using this table, take the actual number of fixtures installed, not the fixture unit value. For example, five fixtures would have a probable demand of about 50 percent, while 45 fixtures would have a probable demand of about 25 percent. When a table showing the factors of simultaneous use is not available, a practical way of figuring the probable demand is 30 percent of the maximum fixture demand in gallons.

Many factors affect the flow of water through pipes resulting in a loss of water pressure. Difficult calculations are required to consider all the factors involved that may cause a loss of water pressure. These calculations are beyond the range of this manual. For simple systems, approximate figures are acceptable for most plumbing installations.

Table 7-10 (for galvanized iron pipe) and table 7-11 (for copper tubing) may be used with the maximum fixture demand and the factor of simultaneous use to find the correct size of pipe for water-service lines. The minimum practical size for a water-service line is 3/4 inch. This size should be used even when calculations show that a smaller size could be used.

To continue the example above, the 14 fixtures would have a factor of simultaneous use of about 35 percent. Since the maximum fixture demand was 321 gpm, the water-service line must have a capacity of 35 percent of 321, or 112 gpm. Assuming a length of pipe 60 feet long and a pressure at the main of 40 psi, table 7-10 or 7-11 shows that either a 1 1/2-inch galvanized iron or a 1 1/2-inch copper tubing water-service line would be large enough for the example fixture demand.

Sizing Hot-Water Supply Systems

The hot-water system is that part of the plumbing installation that heats water and distributes it to various fixtures. There are many ways of heating the water, but whichever is used must be able to supply maximum demand. The materials used in hot-water systems are similar to those used in cold-water supply systems. The use

Table 7-9.—Factors of Simultaneous Use

No. of fixtures	Percent of simultaneous use
1-4	50-100
5-50	25-50
51 or more	10-25

Table 7-10.—Capacitiesof Pipe in Gallons Per Minute (Galvanized Iron)

a. 3/8 inch

Pressure at source in pounds per square inch	Length of pipe in feet									
	20	40	60	80	100	120	140	160	180	200
10	5	3	3	2	2	2	----	----	----	----
20	9	5	4	3	3	3	2	2	2	2
30	10	6	5	4	4	3	3	3	3	2
40	----	8	6	5	4	4	4	3	3	3
50	----	9	7	6	5	4	4	3	3	3
60	----	9	7	6	6	5	5	4	4	4
70	----	10	8	7	6	6	5	5	4	4
80	----	----	8	7	7	6	5	5	5	4

b. 1/2 inch

Pressure at source in pounds per square inch	Length of pipe in feet									
	20	40	60	80	100	120	140	160	180	200
10	10	8	5	5	4	3	3	3	3	3
20	14	10	8	6	6	5	5	4	4	4
30	18	12	10	8	8	7	6	6	5	5
40	20	14	11	10	10	8	7	7	6	6
50	----	16	13	11	11	9	8	7	7	7
60	----	18	14	12	12	10	9	9	8	7
70	----	----	15	13	12	11	10	9	8	8
80	----	----	----	----	----	----	----	----	----	----

c. 3/4 inch

Pressure at source in pounds per square inch	Length of pipe in feet									
	20	40	60	80	100	120	140	160	180	200
10	22	14	12	10	8	8	7	6	6	6
20	30	22	18	14	12	12	11	10	10	8
30	38	26	22	18	16	14	13	12	12	10
40	----	30	24	21	19	17	16	16	15	13
50	----	34	28	24	21	19	18	17	16	15
60	----	38	31	26	23	21	20	19	18	17
70	----	----	34	29	25	23	22	21	19	18
80	----	----	36	30	27	24	23	22	21	20

d. 1 inch

Pressure at source in pounds per square inch	Length of pipe in feet									
	20	40	60	80	100	120	140	160	180	200
10	40	28	22	18	16	15	14	13	12	11
20	55	40	32	27	24	22	20	19	18	16
30	70	50	40	34	30	27	25	23	22	20
40	80	58	45	40	35	32	29	27	25	24
50	----	65	57	45	40	36	33	31	29	27
60	----	70	58	50	44	40	36	34	32	30
70	----	76	63	54	45	42	40	37	34	32
80	----	----	65	57	47	43	39	37	35	33

Table 7-10.—Capacities of Pipe in Gallons Per Minute (Galvanized Iron)—Continued

e. 1 1/4 inch

Pressure at source in pounds per square inch	Length of pipe in feet									
	20	40	60	80	100	120	140	160	180	200
10	80	55	45	37	35	30	27	25	26	24
20	110	80	65	55	50	45	41	38	36	34
30	----	100	80	70	60	56	51	47	45	42
40	----	----	95	80	72	65	60	56	52	50
50	----	----	107	92	82	74	68	63	60	55
60	----	----	----	102	90	81	75	70	65	62
70	----	----	----	----	97	88	82	74	69	67
80	----	----	----	----	105	95	87	79	74	72

f. 1 1/2 inch

Pressure at source in pounds per square inch	Length of pipe in feet									
	20	40	60	80	100	120	140	160	180	200
10	120	90	70	60	55	50	45	40	40	35
20	170	130	100	90	75	70	65	60	55	55
30	----	160	130	110	100	90	80	75	70	65
40	----	170	150	130	110	100	90	90	80	80
50	----	----	170	140	130	120	110	100	90	90
60	----	----	----	160	140	130	120	110	100	100
70	----	----	----	170	150	140	130	120	110	100
80	----	----	----	----	160	150	140	130	120	110

g. 2 inch

Pressure at source in pounds per square inch	Length of pipe in feet									
	20	40	60	80	100	120	140	160	180	200
10	240	160	130	110	100	90	90	80	80	70
20	300	240	200	160	150	140	130	120	110	100
30	----	300	240	200	180	160	150	140	140	130
40	----	----	280	240	220	200	180	160	160	150
50	----	----	----	280	240	220	200	200	180	160
60	----	----	----	----	280	240	220	200	200	180
70	----	----	----	----	300	260	240	220	220	200
80	----	----	----	----	----	280	260	240	220	220

Table 7-11.—Capacities of Pipe in Gallons Per Minute (Copper Tubing)

a. 1/2 inch

Pressure at source in pounds per square inch	Length of pipe in feet									
	20	40	60	80	100	120	140	160	180	200
10	8	5	4	3	3	2	2	2	2	2
20	12	8	6	5	5	4	4	3	3	3
30	15	10	8	7	6	5	5	4	4	4
40	17	12	9	8	7	6	6	5	5	4
50	----	14	10	9	8	7	6	6	5	5
60	----	15	12	10	9	8	7	7	6	6
70	----	----	13	11	10	9	8	7	7	6
80	----	----	14	12	10	10	8	8	7	7

b. 5/8 inch

Pressure at source in pounds per square inch	Length of pipe in feet									
	20	40	60	80	100	120	140	160	180	200
10	12	8	7	6	5	5	4	4	3	3
20	18	12	10	9	7	6	6	5	5	5
30	22	16	12	10	9	9	8	7	6	6
40	26	18	14	12	10	10	9	8	8	7
50	----	22	16	14	12	11	10	9	9	8
60	----	24	18	16	14	13	12	11	10	9
70	----	----	20	18	15	14	13	12	11	10
80	----	----	22	19	16	15	14	13	12	11

c. 3/4 inch

Pressure at source in pounds per square inch	Length of pipe in feet									
	20	40	60	80	100	120	140	160	180	200
10	20	14	10	10	8	8	6	6	6	5
20	30	20	16	14	12	10	10	10	8	8
30	36	26	20	17	15	14	13	11	10	8
40	----	30	24	20	18	16	15	14	13	12
50	----	34	28	24	20	18	16	16	14	14
60	----	36	30	26	22	20	18	18	16	16
70	----	----	32	28	24	22	20	18	18	16
80	----	----	36	30	26	24	22	20	18	18

d. 1 inch

Pressure at source in pounds per square inch	Length of pipe in feet									
	20	40	60	80	100	120	140	160	180	200
10	50	30	24	20	18	16	14	14	12	12
20	70	45	36	30	26	24	22	20	18	18
30	80	55	45	38	34	30	28	26	24	22
40	----	65	55	45	40	36	32	30	28	26
50	----	75	60	50	45	40	36	34	32	30
60	----	80	65	55	50	45	40	38	36	34
70	----	----	70	60	55	50	45	40	38	36
80	----	----	80	65	60	50	50	45	40	40

Table 7-1l.—Capacities of Pipe in Gallons Per Minute (Copper Tubing)—Continued

e. 1 1/4 inch

Pressure at source in pounds per square inch	Length of pipe in feet									
	20	40	60	80	100	120	140	160	180	200
10	80	55	42	37	32	30	27	25	22	22
20	110	80	65	55	47	42	40	35	35	32
30	----	105	80	70	60	55	50	45	42	40
40	----	110	95	80	70	65	60	55	50	47
50	----	----	110	90	80	70	65	60	57	55
60	----	----	----	105	90	80	75	70	65	60
70	----	----	----	110	100	90	80	75	70	65
80	----	----	----	----	105	95	85	80	75	70

f. 1 1/2 inch

Pressure at source in pounds per square inch	Length of pipe in feet									
	20	40	60	80	100	120	140	160	180	200
10	130	90	70	60	50	45	40	40	35	35
20	170	130	100	90	75	70	65	60	55	50
30	----	170	130	110	100	90	80	75	70	65
40	----	----	155	130	115	105	95	88	80	77
50	----	----	170	150	130	120	108	100	90	88
60	----	----	----	165	145	130	120	110	105	98
70	----	----	----	170	160	142	130	122	113	106
80	----	----	----	----	170	155	140	130	122	115

g. 2 inch

Pressure at source in pounds per square inch	Length of pipe in feet									
	20	40	60	80	100	120	140	160	180	200
10	280	180	150	145	110	100	90	85	80	70
20	320	280	220	190	165	160	140	125	120	110
30	----	320	280	240	210	180	170	160	150	140
40	----	----	320	280	240	220	200	190	175	160
50	----	----	----	320	280	250	230	210	200	190
60	----	----	----	----	300	280	260	240	220	200
70	----	----	----	----	320	300	280	260	240	230
80	----	----	----	----	----	320	300	280	260	240

of copper has become the most popular because of copper's ability to resist corrosion that increases in proportion to the temperature of the water. Sizing of the piping for a hot-water system is done the same way as for a cold-water system.

The layout of a hot-water system is designed to carry heated water from a storage unit to plumbing fixtures. Installation planning begins with the water-heating device and a main supply line from that device. The system should be graded to a centrally located drip cock near the water heater to allow for draining the system when maintenance is required. Water for the individual fixtures located throughout the facility is taken off the main hot-water supply by risers as needed. Each fixture riser should have a valve to make repair work easier.

Buildings of considerable floor area or of multifloor construction have the added problem of supplying hot water to the fixture as soon as possible after the tap is opened. In a one-pipe system (such as that used for cold-water supply), a lag occurs from the time the hot-water tap is opened until the heated water travels from the the water-heating device to the fixture. To overcome this lag, a circulating water supply system is often used. (See fig. 7-2.)

The circulating supply system is a two-pipe system in which hot water flows from the heating device through the main fixture risers and returns to the heating device. This type of looped system

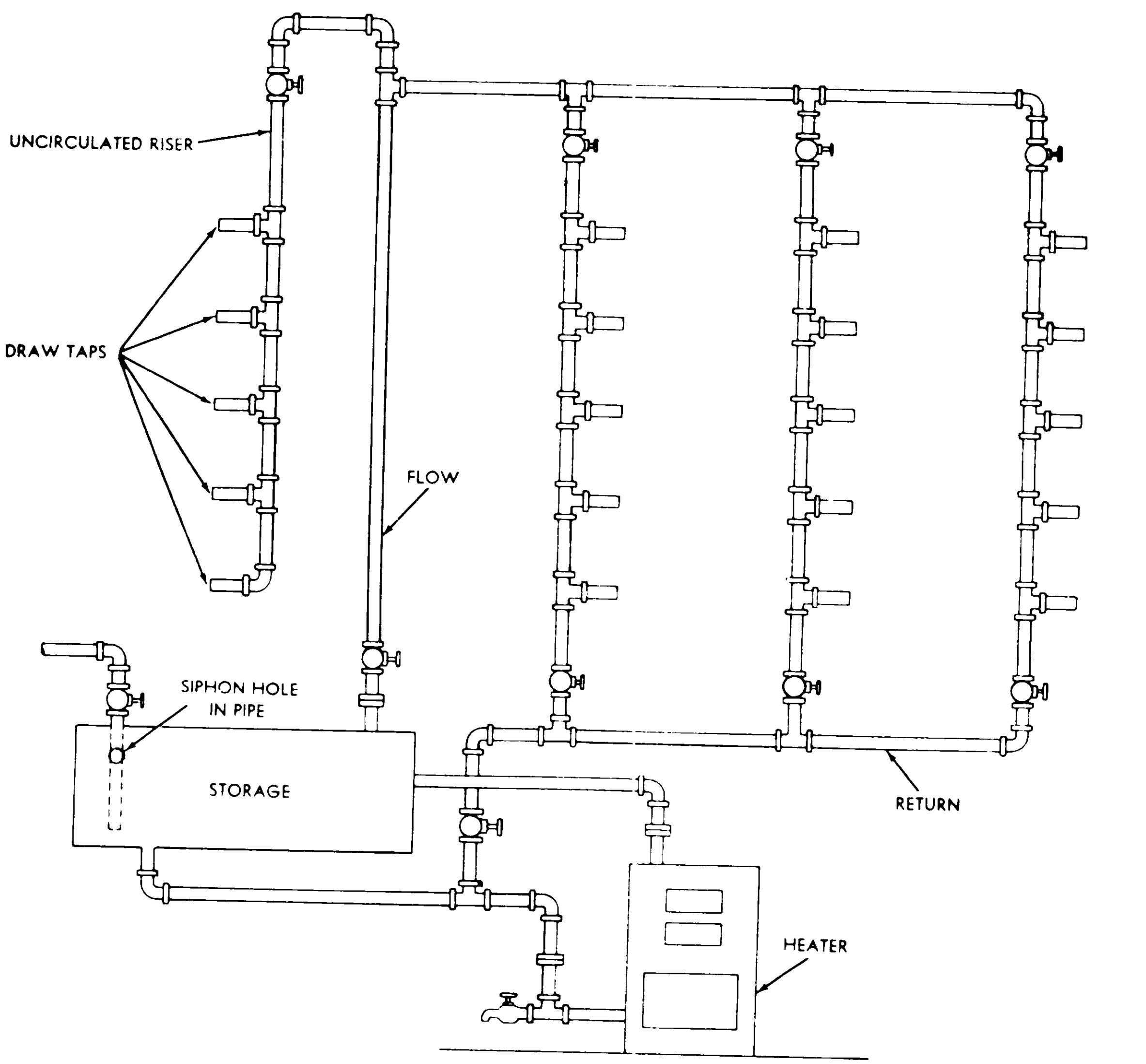

Figure 7-2.—Hot-water circulating supply system.

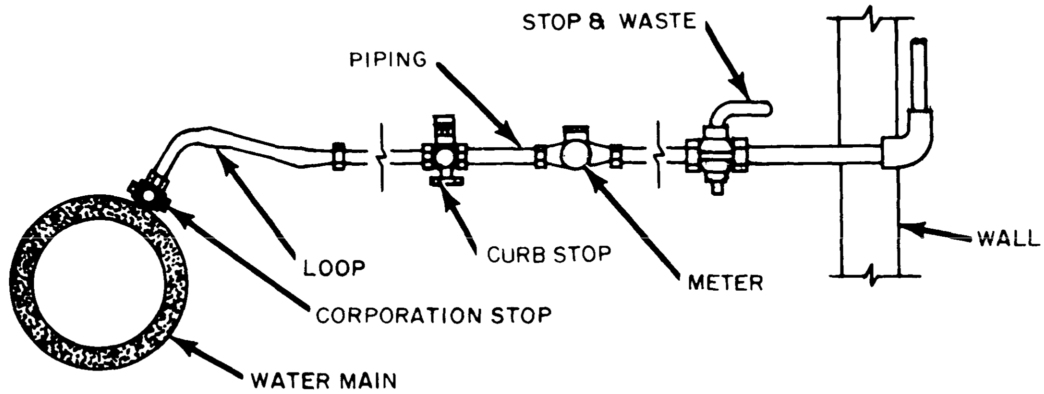

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Figure 7-3.—Typical building water supply system.

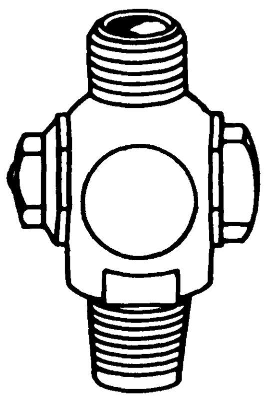
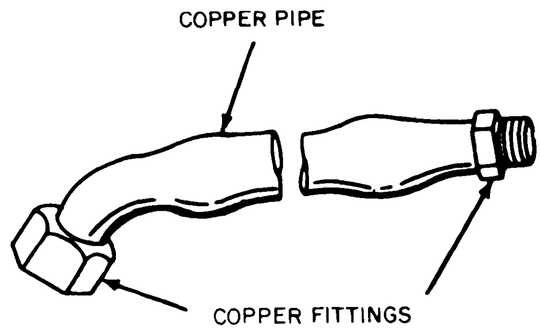


Figure 7-4.—Corporation stop.



87.341

Figure 7-5.—Flexible gooseneck connector.

provides for circulation of the hot water at all times. The circulation is created because warm water tends to rise and cold water tends to fall.

The circulating system shown in figure 7-2 is known as an overhead feed and gravity-return system because of its construction. This type of system tends to become airbound, preventing circulation of the hot water. Since air collects at the highest point of the distribution piping, the most practical way to relieve the air lock is to connect an uncirculated riser to the line at that point. Any air lock that develops is relieved when a fixture on the uncirculated riser is used.

Piping and Fitting General Requirements

A typical building water-service line is shown in figure 7-3. This line is composed of a corporation stop, a flexible connector, a curb stop, a stop and waste valve, and a meter stop or gate valve.

The corporation stop is installed at the location (fig. 7-4) on the water main where a tap is made. Its function is to make the removal of the taping machine and the installation of the remaining fittings easier by securing the water flow from the tap. A corporation stop may not be needed if you are installing building service lines from a newly installed, unpressurized water main.

When you install the line between the corporation stop and the curb stop, use some type of flexible connection for joining the pipe to the corporation stop. This flexible connection protects the corporation stop from strain or damage that can result from any movement of the water main or service pipe because of settling, earth movement, or expansion and contraction.

Several types of flexible connectors are used. The type you choose will depend on the type of material used for the supply line. A *gooseneck* (fig. 7-5) is used when galvanized iron or steel pipe is used as the supply line. It consists of a length of copper pipe with fittings wiped or soldered on each end. Another flexible connector is the *swing joint* type commonly used with galvanized iron or steel service lines. (See fig. 7-6.) This connection consists of two elbows separated by a short section of pipe or a nipple. Next is the *expansion loop* (fig. 7-7) used when copper tubing is used as the service line.

A curb stop must be provided in every service line to conform to the *National Standard Plumbing Code,* paragraph 10.12.1. (See fig. 7-8.) The curb stop provides an accessible shutoff of the water supply to the building.

Next, a stop and waste valve (fig. 7-9) will be installed to conform to the *National Standard Plumbing Code,* paragraph 10.12.2. This valve is used to drain the building water system. It must be installed at a point where drainage by gravity can be achieved. When the valve is turned off, drainage will occur through a drilled passage in the valve body.

Finally, a meter stop is installed when a water meter is to be included in the service line (fig. 7-10). It is installed on the pressure side of the meter and can be used for convenient securing of the water supply to the building. Where no meter is used, a simple gate valve may be provided for convenient use when repairing or maintaining the building water lines.

Each fixture to be installed requires a fixture stop valve and a certain size branch and riser piping. Branch lines are calculated in the same fashion as service supply lines. Risers for each

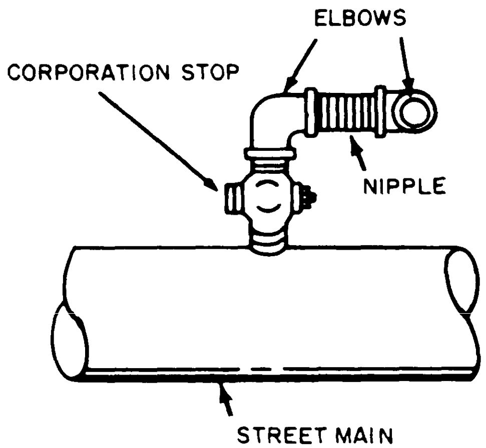


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Figure 7-6.—Typical swing joint.

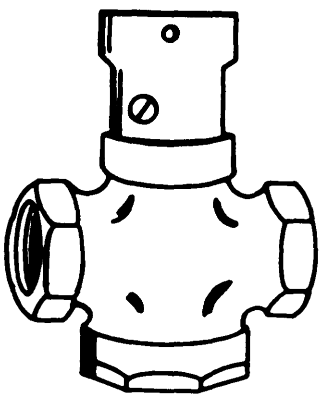

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Figure 7-8.—Curb stop.

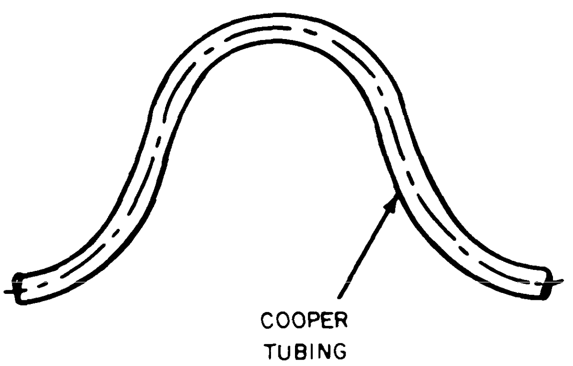

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Figure 7-7.—Expansion loop.

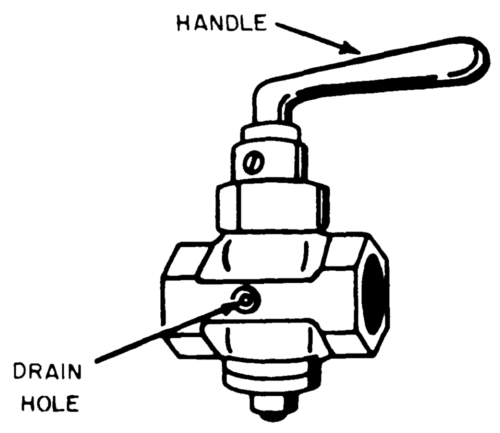

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Figure 7-9.—Stop and waste valve.

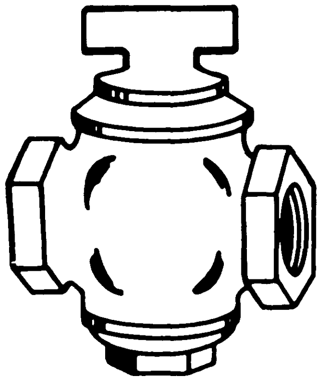

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Figure 7-10.—Meter stop.

individual fixture are sized according to table 7-12 for both cold- and hot-water risers. A typical layout for branch lines and fixture risers is shown in figure 7-11.

For more complete information, refer to the latest edition of the *National Standard Plumbing Code.* The code will guide you in determining all required installation considerations of facility water supply system needs.

CORROSION PREVENTION AND PROTECTION

As a Utilitiesman, you must consider the effects of corrosion on the equipment that you are installing. When planning a project, the

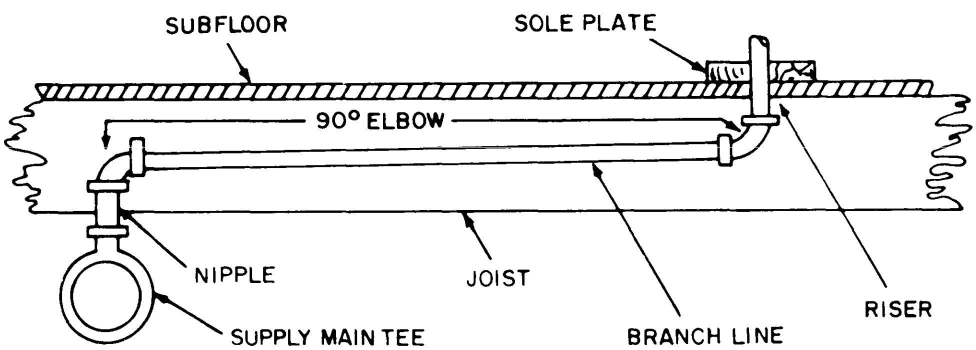

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Figure 7-11.—Water supply branch line.

Table 7-12.—Water Pipe Size Chart for Plumbing Fixtures

PLUMBING FIXTURE	PIPE DIAMETER (inches)
Dishwasher	1/2 or 3/4
Water closet tank	1/2
Water closet flushometer valve	1
Urinal with flushometer valve	1/2
Lavatory	1/2
Shower bath	1/2
Kitchen sink	1/2
Slop sink	1/2
Scullery sink	3/4
Laundry tray	1/2
Drinking fountain	1/2
Hot-water heater (domestic)	3/4
Bathtub	1/2

necessary materials and equipment required for galvanic cathodic protection of underground pipes and fittings must be considered. First you must understand what corrosion is and how it occurs.

TYPES OF CORROSION

Man has had corrosion problems to contend with ever since he started making articles out of metal. For thousands of years, the only fact known about corrosion was that it would affect some metals more than others. For example, iron, one of the most abundant and useful metals, corrodes very much; whereas metals such as gold, platinum, and silver corrode very little. Later, men began to study corrosion to find out what caused it. As might be expected, many theories were proposed to explain corrosion and its causes. Among the many theories, the electrochemical theory is most generally accepted as an explanation of corrosion.

The electrochemical theory of corrosion is best explained by the action that takes place in a galvanic cell. A galvanic cell can be produced by placing two dissimilar metals in a suitable electrolyte, as shown in figure 7-12. The resulting electrochemical reaction develops a potential difference between these metals. This causes one metal to be negative or anodic and the other metal to be positive or cathodic. In a dry cell battery, the zinc case is the anode and the carbon rod the cathode. Now, when an external electrical circuit is completed, current flows from the zinc case into the electrolyte, taking with it particles of zinc. This is an example of galvanic corrosion of the zinc case. It is this electrochemical action that illustrates the electrochemical theory.

Corrosion may be divided into several types, such as uniform corrosion, localized corrosion, and compositional corrosion. Each type will be explained in the following paragraphs.

Uniform Corrosion

Uniform corrosion is caused by direct chemical attack. An example of this type of corrosion is zinc exposed to hydrochloric acid. If you examine the surface of zinc in a solution of hydrochloric acid, you will find that the entire surface is corroding. Furthermore, if the zinc is left in the acid long enough, it will be dissolved by the acid.

Localized Corrosion

Localized corrosion is caused by the electrolytic action of a galvanic cell. A local galvanic action is set up when there is a difference of potential between the areas on a metallic surface that is an electrolyte. Localized corrosion may be in the form of pits, pockets, or cavities due to the deterioration or destruction of metal.

Localized corrosion may develop under a number of various conditions when different types

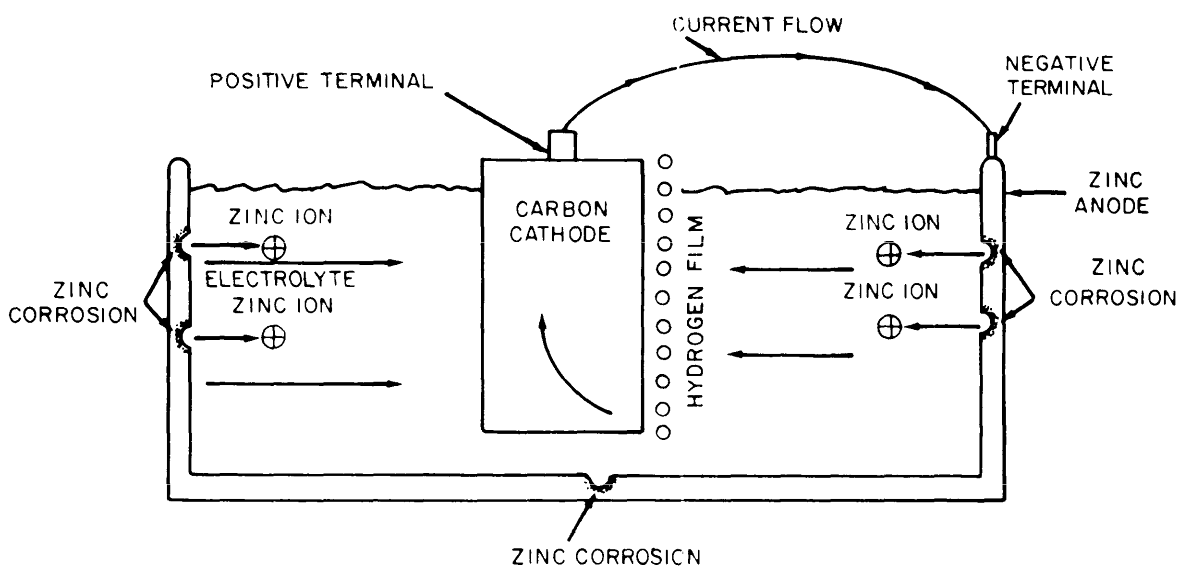

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Figure 7-12.—Galvanic cell showing internal galvanic action.

of equipment are buried in the ground. Some examples of localized corrosion are discussed in the following paragraphs.

● Corrosion due to mill scale. The mill scale embedded in the walls of iron pipe during its manufacture is one cause of pipe corrosion. It actually becomes the cathodic area, the iron pipe the anodic area, and the moist soil the electrolyte, as shown in figure 7-13. Current leaves the iron pipe wall and passes through the electrolytic soil to the mill scale. This electrochemical action causes severe pitting of the pipe metal at the anodic areas. Continued action of this type will eventually weaken the pipe to the extent of failure.

● Corrosion due to cinders. Another type of corrosion occurs when iron pipe is laid in a cinder-fill in direct contact with the cinders. The cinders and the iron pipe make up the dissimilar metals. The pipe forms the anodic area, the cinders form the cathodic area, and the highly ionized soil serves as the electrolyte. The current leaves the pipe through the soil to the cinders and returns to the pipe. Severe corrosion occurs at the points where the current leaves the pipe.

● Corrosion due to dissimilarity of pipe surface. This type of galvanic corrosion occurs when there are bright or polished surfaces on some areas of the pipe walls in contact with suitable electrolytic soil. These bright surfaces become anodic to the remaining pipe surfaces. In highly ionized soil, the polished surfaces corrode at an accelerated rate, thus weakening the pipe at that point.

● Corrosion due to different soil conditions. This is a general corrosion problem, especially prevalent in highly alkaline areas. Corrosion currents leave the pipe wall and pass into compact soils and enter the pipe wall from light sandy soils. The intensity of the corrosion currents and the resulting rate of corrosion at the anodic areas of the pipe are directly proportional to the conductivity of the soil.

● Corrosion due to stray currents. Direct current circuits that pass in and out of an electrolyte usually cause stray currents, many of which are a direct cause of corrosion. Corrosion does not occur at the point where the current enters the structure, because it is catholically protected. However, at the section where the current leaves the structure, severe stray current corrosion occurs. Over a period of a year, this type of corrosion has been known to displace as much as 20 pounds of pipe wall for every ampere of current.

● Corrosion due to bacteria. Biological corrosion is another distinct type of corrosion caused by electrolytic or galvanic cell action. It is the deterioration of metals by corrosion processes that occurs as either a direct or an indirect result of the metabolic activity of certain minute bacteria, particularly in water or soil envirnments. These organisms that cause bacterial corrosion are bacteria, slime, and fungi.

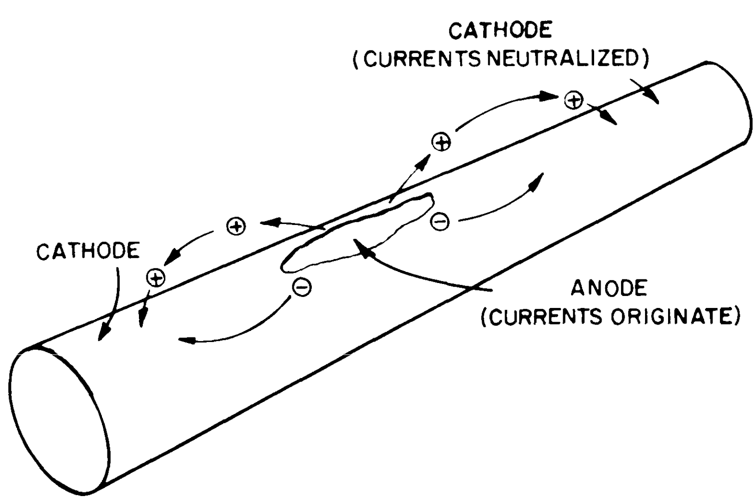

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Figure 7-13.—Pipe with corroding (anode) and noncorroding (cathode) areas.

Microbiological corrosive action in the soil is due to physical and chemical changes in the soil caused by the presence of these organisms. Some bacteria are responsible for the production of active galvanic cells. These bacteria are mostly found in highly waterlogged, sulfate-bearing, blue clay soils. The bacteria concentration, as well as the corrosion rate, varies considerably with the different seasons of the year. Cast-iron and steel pipes are corroded mostly by sulfide production.

Compositional Corrosion

Compositional corrosion alters the composition of metals. Some of the specific types of compositional corrosion are discussed in the following paragraphs.

- Dezincification. This is a selective type of corrosion that occurs in copper and zinc alloys. When alloys of this kind (brasses) are exposed to this type of corrosion, the zinc dissolves out of the alloy and leaves only the copper.

- Graphitization. Another type of compositional corrosion is graphitization or graphitic softening. It is a peculiar form of disintegration that attacks grey cast iron. Cast iron is an alloy made of iron and carbon, the carbon being in the form of graphite. When cast iron with such a composition is subjected to graphitization, the iron dissolves out and leaves only the graphite. This action leaves cast-iron pipes and other similar equipment weakened mechanically. However, after graphitization corrosion occurs, the graphite pipe may last for many years if it is not subjected to any mechanical forces or sudden pressures. The action of this type of corrosion is similar to dezincification.

- Hydrogen embrittlement. This is a term applied to metal that becomes brittle because of the action of some form of corrosion that causes the formation of hydrogen on its surface. When hydrogen forms on the surface of steel, the action of the hydrogen may form blisters or actually embrittle the metal. Hydrogen liberated near the surface of steel in an electrolyte will diffuse into the metal quite rapidly. The hydrogen picked up by the steel is in an atomic state and causes the steel to become brittle.

When the production of atomic hydrogen on the surface of the metal stops, the hydrogen leaves the metal in a few days and the metal again regains its original ductility.

Stress Fatigue of Metals

Corrosion affects metals that are under stress. The action caused by stresses on a pipeline or structure is due to the shifting of the various rocks and soils of the earth. Usually a complete pipeline is not under stress; certain sections are under stress while adjacent sections are not. Because of these pressures and strains, localized electrochemical action takes place. The section of the pipe or structure under stress becomes anodic, whereas the unstressed sections become cathodic. In this way, the pipe under stress begins to corrode and weaken because of the action of corrosion.

Corrosion Caused by Nonelectrolytes

Nonelectrolytes are materials that will not conduct electricity. These materials include nonelectrolytic vapors, liquids, and bacterial organisms. Since they do not conduct electricity, they do not, in themselves, cause corrosion.

NONELECTROLYTE GASES AND VAPORS.— Nonelectrolytic gases and vapors usually must be subjected to high temperatures before corrosive action can take place. Hydrogen sulfide causes scaling of iron at temperatures from 1400° to 2000°F. High-chromium alloy steels resist this type of corrosion best. The only remedy for this type of corrosion is to keep the gases away from the metal or use a metal that can resist corrosion.

High-carbon steels are attacked by hydrogen at temperatures above 750°F. This hydrogen combines with the carbon grains in the steel and causes the metal to weaken at the grain boundaries between the iron and carbon.

Oxygen will combine directly with most metals at high temperatures. The temperature at which oxygen will combine with the metals depends mostly upon the type of metal. In the process of cutting iron with an oxyacetylene torch, the oxygen combines with the iron.

NONELECTROLYTIC FLUIDS.— Nonelectrolytic fluids include such liquids as pure water, lubricating oils, fuel oils, and alcohols. These fluids do not cause corrosion, but corrosion does occur in storage tanks that contain these liquids and in pipelines that carry them. The corrosion is not caused by the nonelectrolyte liquids, but by the foreign products in them. For example, if impure water is introduced into an oil pipeline, the water will cause the inside of the pipe to corrode. The water collects on the inside of the pipe because the pipe is usually cooler than the oil. In a storage tank, the water will settle to the bottom of the tank because water is heavier than oil, and will cause the bottom to corrode. Hydrogen sulfide and sulphur dioxide may also be introduced into the pipeline to add to the corrosiveness of the water that collects on the metal. The only way to prevent corrosion from this source is either to coat the inside of the pipeline and tanks with a protective film or to remove the water from them.

Bacterial Organisms

Bacterial organisms may also cause microbiological corrosion. Colonies of bacteria that live close to the metal surface in stationary slimy deposits produce corrosive substances such as carbon dioxide, hydrogen sulphide, ammonia, and organic and inorganic acids. These corroding substances are found only in the locality of the colony and may be undetected in the surrounding water or soil. Bacteria that cause corrosion in this way need to produce only small amounts of corrosive products for localized attack. However, colonies of bacteria that do not produce corrosive products may act as a protective film around the metal, causing unequal distribution of electrical potential, which gives rise to local anodes and cathodes. In this way, the production of local cells will cause increased corrosive action.

Biological corrosion is extremely difficult to control, since the organisms are very resistant to normal methods of sterilization. Probably the most logical method to reduce microbiological corrosion is by the use of some barrier coating between the environment and the metal.

Corrosion Caused by Electrolytes

An electrolyte is any substance that conducts electricity. It conducts electricity because it contains ions that carry electrical charges, either negative or positive, that move in electrical fields. Some of the more important electrolytes are discussed in the following paragraphs.

ATMOSPHERIC CONDITIONS.— Corrosion due to atmospheric conditions is caused mainly by the water in the atmosphere. Pure water is a nonelectrolyte, but because water is a universal solvent, it is not found to be pure very often. Rain water is often considered to be pure, but this is not true. As rain falls to the ground, it dissolves gases out of the atmosphere and becomes impure. For this reason, any water vapor in the atmosphere is also impure. If a piece of metal is exposed to atmospheric air, and the metal is cooler than the air, water vapor from the air will collect on the surface of the metal. The layer of water on the metal maybe so thin that it cannot be seen; but there is enough of it, if impure, to start corrosion. In this case, when the gases dissolve into the water, the water becomes an electrolyte. When metal is exposed to an electrolyte, galvanic cells are produced on the surface of the metal, since there are impurities in it. Each one of these cells starts to act on the metal, causing corrosion by electrochemical action.

WATER AND WATER SOLUTIONS.— If metal is exposed to water or water solutions, corrosion is likely to occur if the water or metal is impure. If the water or metal is pure, corrosion probably will not occur; however, these conditions seldom exist in nature. Impurities in the water and metal produce galvanic cells that cause corrosion.

CHEMICAL AGENTS.— Chemical agents such as acids and salts also cause corrosion. When these agents are present in the environment, direct chemical attack on metal is the result. For example, if a piece of zinc is exposed to hydrochloric acid, a definite chemical reaction takes place. The zinc and hydrochloric acid combine, producing zinc chloride and hydrogen. This action continues until the zinc is completely dissolved or the acid is too weak to act on the zinc. Corrosion causes the zinc to dissolve.

Another example that may be used to illustrate corrosion through the use of a chemical agent is to place aluminum in a lye solution. The lye will pit (corrode) the aluminum as long as chemical action continues between the aluminum and lye.

MATERIALS LEAST LIKELY TO BE AFFECTED BY SCALE AND CORROSION

Whenever installing various types of plumbing equipment in areas where corrosion is active, you should select equipment made of materials least affected by corrosion. To prevent electrochemical action in plumbing equipment, the equipment should be made of materials that are not affected by electrolysis. Plastic materials such as polyethylene polyester and polyvinyl chloride are not acted upon by corrosion. Glass is another material that is not acted on by corrosion. (This is why hot-water tanks are lined with glass.) Other materials used for the manufacture of pipe that resists corrosion are vitrified clay, cement, fiber, asbestos, and rubber. Glass fibers reinforced with epoxy or polyester resins are also resistant to corrosion.

Dielectric bushings may be installed to stop electrolytic action in plumbing systems or wherever dissimilar metals are used. These bushings are made of nylon and are usually colored. They withstand pressures to 100 psi and temperatures up to 300°F. The bushings are usually placed in pipe systems as recommended by the manufacturer. Some metals least likely to be affected by corrosion are copper, brass, Monel, and stainless steel.

COATINGS AND WRAPPINGS FOR CORROSION PROTECTION

Coatings and wrappings are commonly used to combat corrosion on exterior piping systems. There are many different types of coatings such as asphalts, coal tars, plastics, mastics, greases, and cements. These coatings are considered to be insulating materials, but each is not effective in all environments. Each one was developed for a certain type of corrosive environment.

Asphalt Coatings

Asphalt base coatings are the most common type of protective coatings used. They are produced from petroleum residue and natural sources. Asphalt base coatings can take considerable abrasion, impact, and temperature changes wit bout creating a corrosive condition. However, they absorb a considerable amount of water and dissolve easily into a form of petroleum product.

Coal Tar Coatings

Coal tar coatings are commonly used on pipelines. They possess continuity, hardness, adhesion, and corrosion resistance. Coal tar coatings are less expensive than asphalt coatings. They do not have a very good impact resistance, and a wide temperature change often causes the surface to crack.

Paint Coatings

Some of the most important paint coatings are coal tar, asphalt, rubber, and vinyl.

Coal tar paints have the outstanding characteristics of low permeability and resistance to electrolytic reaction. They are not affected by the action of water. These paints are recommended for piers, marine installations, flood control structures, sewage disposal plants, and industrial concrete pipelines.

Asphalt paints are weather resistant and durable against industrial fumes, condensation, and sunlight action. Because of their resistance against water solvency, they are used on steel tanks and concrete reservoirs.

Rubber base paints are very resistant to acids, alkalies, salts, alcohols, petroleum products, and inorganic oils. The resistance of these products makes them ideal for use on the inside of metallic and concrete storage tanks. If these structures are submerged in water or are under ground, a special form of this paint should be used because of condensation.

Vinyl paint is one of the many synthetic resin base paints. These paints dry to a film that is tough, abrasionproof, and highly resistant to electrolysis. They are odorless, tasteless, nontoxic, and nonflammable. The film is especially resistant to oils, fats, waxes, alcohols, petroleums, solvents, formic acid, organic acids, ammonium hydroxides, and phenols. Because of these characteristics, vinyl paint is very applicable for tanks, pipelines, wellheads, offshore drilling rigs, pipe used in oil industries, railroad hopper cars, dairy and brewery equipment, storage tanks, and concrete exposed to corrosive environments.

Grease Coatings

Grease is another material used to form a protective coating on structures. It is usually made from a petroleum base and resembles paraffin or wax, Grease can be applied either hot or cold. However, it must be protected by some type of wrapping to keep the grease from being displaced or absorbed by the backfill soil when it is applied to underground surfaces.

Concrete Coatings

Concrete coatings have been used with success when properly applied to pipelines to be laid in highly corrosive soils, such as areas containing acid mine drainage or in brackish marshes. Well-mixed concrete, usually a mix of one part portland cement to two parts sand, may be applied to pipelines. The thickness of the coating applied may be up to 2 inches. If the concrete is properly mixed and tamped around the pipe, it may last 40 years. However, concrete has a tendency to absorb moisture and crack, which in many ways limits its use. In fact, in places where the coating cracks, electrolysis immediately starts to corrode the metal. This corrosion can be partially prevented by painting the pipe with a bituminous primer before coating it.

Metallic Coatings

Metallic coatings such as galvanizing (zinc coating) are very effective in protecting metallic structures or pipes against atmospheric corrosion. This type of coating is ideal for cold-water lines and metals exposed to normal atmospheric temperatures. However, metals such as iron corrode rapidly when used in high-temperature equipment because at a critical temperature of approximately 140°F iron becomes anodic to zinc. This results in the iron's becoming the sacrificial anode that corrodes readily.

Plastic Wrapping

Plastic tapes for wrapping come in rolls. They may be procured in various widths. The tape is wrapped around the pipes before they are laid in the trench. The wrappings are applied by a simple device that is clamped on the pipe and turned by the UT. Pipe joints are wrapped after the pipes are laid in the trench.

GALVANIC CATHODIC PROTECTION

Galvanic cathodic protection is a method used to protect metal structures from the action of corrosion. As explained before, galvanic cell corrosion is the major contributing factor to the deterioration of metal by electrochemical reaction. The area of a structure that corrodes is the anode or positive side of the cell. Corrosion occurs when the positive electric current leaves the metal and enters the electrolyte. Galvanic cathodic protection is designed to stop this positive current flow. When the current is stopped, the corrosive action stops and the anodes disappear. This type of protection depends upon the neutralization of the corroding current and the polarization of the cathode metal areas.

METHODS OF GALVANIC CATHODIC PROTECTION

Galvanic cathodic protection is a means of reducing or preventing the corrosion of a metal surface by the use of sacrificial anodes or impressed currents. When sacrificial anodes are used, it is known as the galvanic anode method. If impressed currents are used, it is known as the impressed current method. These two methods can be used separately or with each other, depending upon the corrosive characteristics of the electrolyte surrounding the structure.

Galvanic Anode Method

The galvanic anode method of cathodic protection uses an electrode referred to as a sacrificial anode that corrodes to protect a structure. This sacrificial anode is electrically connected to and placed in the same electrolytic area of the structure. The anode used to protect iron or steel structures should be made of magnesium or zinc so it will produce a sufficient potential difference to cause the structure to become a cathode. The action of this type of galvanic protection causes the electric current to flow from the sacrificial anode through the electrolyte to the structure to be protected. The electrical connection between the two metals completes the circuit and allows the current to return to the corroding metal. The sacrificial anode becomes the anode of the established dissimilar metal galvanic cell, and the structure to be protected becomes the cathode. The current from the sacrificial anode is intense enough to oppose or prevent the positive current from leaving the anodes in the structure to be protected. These structure anodes are then suppressed, and the metal in the structure becomes a cathode. The prevention of these positive currents from the anodic areas in the structure reduces the corrosion rate to almost zero.

Galvanic cathodic protection is used in areas where the corrosion rate is low and electric power is not readily available. A typical example of galvanic cathodic protection is shown in figure 7-14.

Impressed Current Method

The impressed current method of cathodic protection is designed to protect large metal structures located in corrosive areas. With this method of protection a source of alternating current is required. Also, a rectifier is needed to obtain the required direct current potential.

The basic principle of the impressed current method is merely the application of the galvanic cell reaction. The component parts of this method are the cathode (the metal structure to be protected), the anode (made of suitable anodic material), the electrolyte or ground (the ionized corrosive material), and the rectifier and various connections that serve to complete the electrical circuit. The operation of this method depends on the rectifier forcing direct current from the anode through the electrolyte (ground) to the metal structure to be protected. This method causes the metal structure to be the cathode, suppresses the anodic currents from it, and, in turn, prevents corrosion of the structure. An impressed current method of cathodic protection is shown in figure 7-15.

FIELD TEST EQUIPMENT FOR CATHODIC PROTECTION

The items of field test equipment that the UT uses to make tests when installing, operating, and maintaining cathodic protection systems are the volt-millivoltmeter, multicombination meter, resistivity instrument, buried pipe locator, and the protective coating leak detector. This equipment is discussed in the following paragraphs.

Volt-Millivoltmeter

In corrosion and cathodic protection testing in the field, it is necessary to measure the potential of the structure being investigated as compared to the earth along the structure and to other metallic structures. It is also necessary to measure the potential of rectifiers, batteries, galvanic anodes, and sometime potentials along the earth's surface to determine the distance being protected. The potentials may vary from millivolts to 20 volts or more. Various types of voltmeters are used for this purpose. One of these instruments is the volt-millivoltmeter. It is a recording instrument designed with a chart that makes one revolution in 24 hours. The instrument will record the variations in potential and reveal the electrolytic conditions around a structure.

Multicombination Meter

The multicombination meter is used quite often in cathodic protection work. It is designed as a combination unit and actually consists of more than one instrument. The meter can be used as a high-resistance voltmeter, an ammeter, a

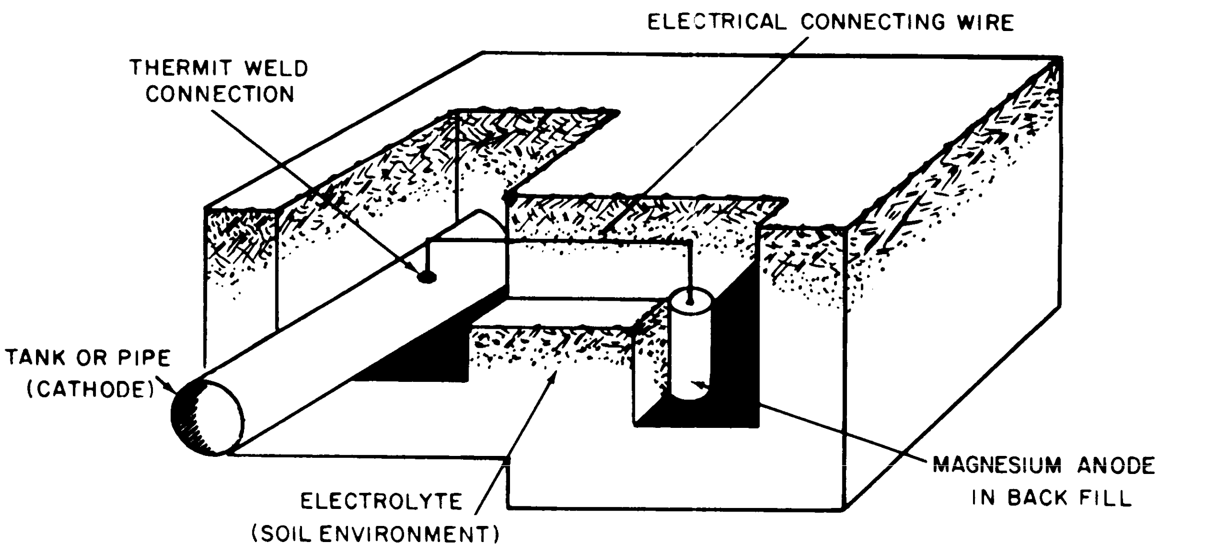

Figure 7-14.—Galvanic cathodic protection.

milliammeter, a low-resistance voltmeter and millivoltmeter, and a potentiometer voltmeter.

The multicombination meter maybe used to measure galvanic anode current between an anode and structure, galvanic current between structures, and potentials as with other types of voltmeters and millivoltmeters.

Resistivity Instruments

Resistivity measuring instruments are units used to test the corrosive action of a soil. Tests regarding soil corrosivity are necessary when designing cathodic protection systems. Information from these tests is used to locate the most corrosive areas where a pipeline is to be laid and the most corrosive areas of an existing pipeline. It is also used to decide the location for anode beds.

One of the simplest methods for making a resistivity test is to use a single probe resistivity meter. It consists of a probe with two electrodes, an indicating instrument, switches, and the required wiring. To use this instrument, the probe is inserted into the ground and current is applied to it. The indicating instrument gives a reading that indicates the corrosiveness of the soil.

Buried Pipe Locator

In the field of cathodic protection work, it is necessary to locate pipes in order to locate interferences in the cathodic protection system. An electronic pipe locator is used for this purpose. The main components of the locator are the directional transmitter and the directional receiver. Each one of these units is carried by an operator. The operators are usually about 30 feet apart. During actual operation the transmitter sends out signals which travel along the pipeline. The receiver, in turn, picks up these signals in varying intensities, depending on the distance the operators are from the pipe. When both operators are directly over the pipe, a maximum response is obtained in the phones and on the visual meter of the receiver. Most pipe can be located easily and accurately in this manner.

Protective Coating Leak Detector

A protective coating leak detector (referred to as a *holiday detector)* is used to detect the imperfections (holidays) in pipe coatings. The holiday leak detector is an instrument that operates on an electric current. When it is being

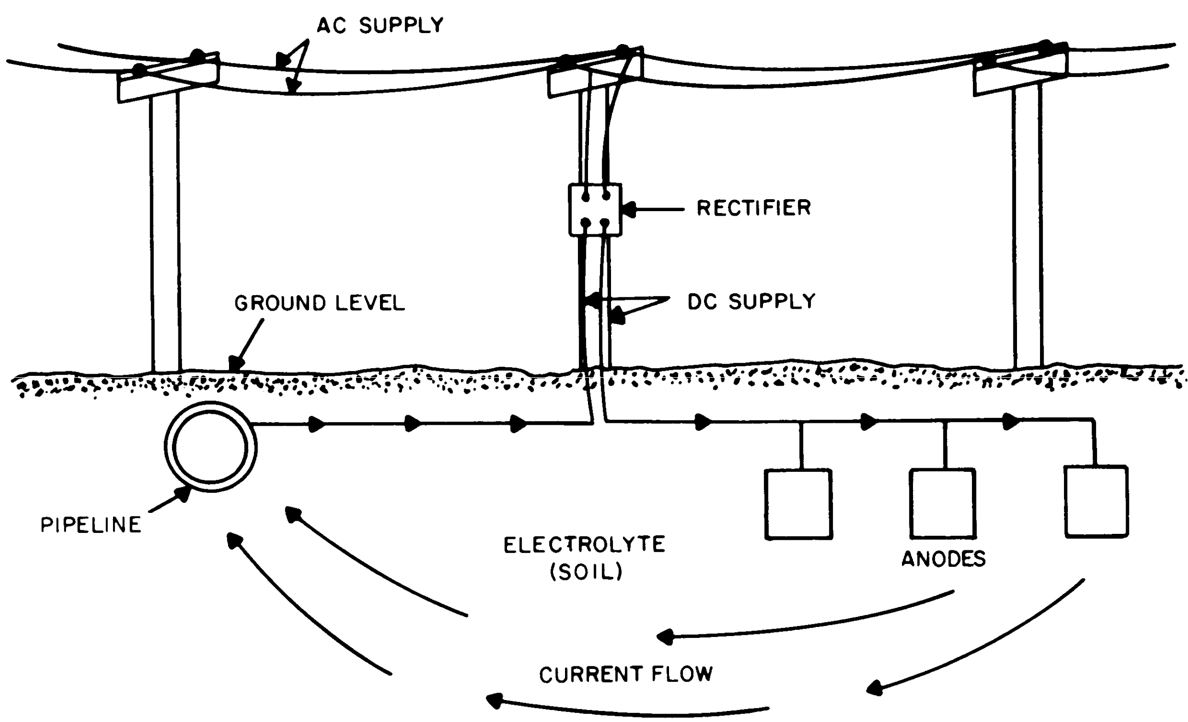

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Figure 7-15.—Impressed current method of cathodic protection.

moved along a pipe that is covered by a coating or wrapping, a completed circuit between it and the pipe reveals a holiday and causes a bell to ring or a bulb to light or a buzzer to sound.

MAINTENANCE OF ANODE SYSTEMS

The anode system of cathodic protection requires little maintenance since there is no power source.

Magnesium and zinc anodes used in the anode system sometimes suffer local or self-corrosion that reduces their efficiency. Replace the anode when the efficiency drops to a minimum. Anode life varies from 5 to 30 years, depending upon the type of anode used. It is conservative to figure that about 17 pounds of magnesium or 25 pounds of zinc are wasted away by electrolysis from an anode per ampere year. To detect the effectiveness of cathodic protection, you should install test stations in anode systems.

MAINTENANCE OF IMPRESSED CURRENT SYSTEMS

The impressed system of cathodic protection requires considerably more maintenance than the anode system. This is because an electrical current is used for the operation of the system. The current may come from any alternating current source. When alternating current is not available, you can use other generating sources to furnish the alternating current. The transformer-rectifier used in the system requires much less maintenance and servicing than other sources of current. However, systematic maintenance procedures must be used to keep these units in operating condition.

The transformer-rectifier set consists of two units, a transformer and a rectifier. The transformer steps the voltage down to a value of 12 to 40 volts. The rectifier changes the alternating current to direct current. Remember to keep all of the connections on this unit airtight.

The materials most often used for anodes with impressed current are aluminum, high-silicon cast iron, and graphite. Scrap iron and steel may be used for anodes since they waste away at a rate of 20 pounds per ampere year. Replace anodes when they are wasted away. Insulated wire that resists electrolytic action must be used to make the connections between the anodes and the structures to be protected. The insulation on existing current-carrying lines should be checked. Replace the wires if they are deteriorating. Ensure that overhead wiring is fastened securely to the poles and that all connections are tight.